

Energy Sustainability as a Global Imperative

Presented at iCAST Colorado Tech Week

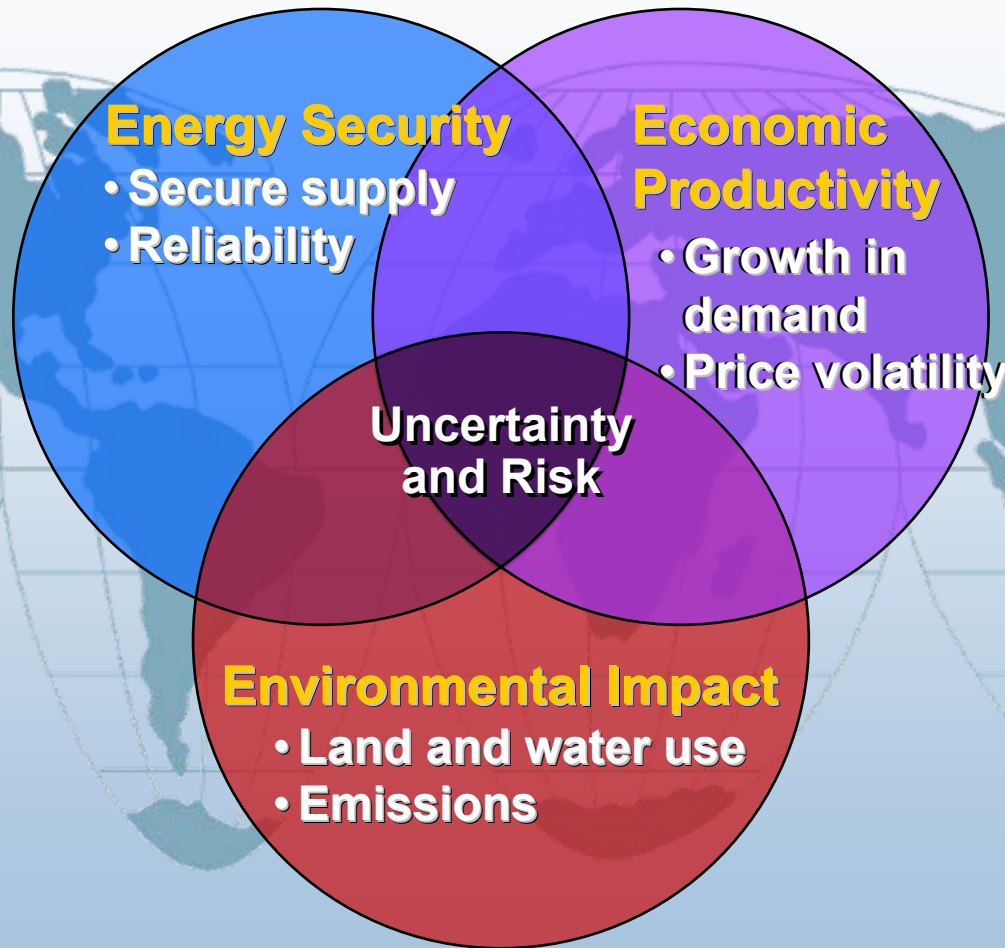
September 18, 2006

Dan E. Arvizu

Director, National Renewable Energy Laboratory

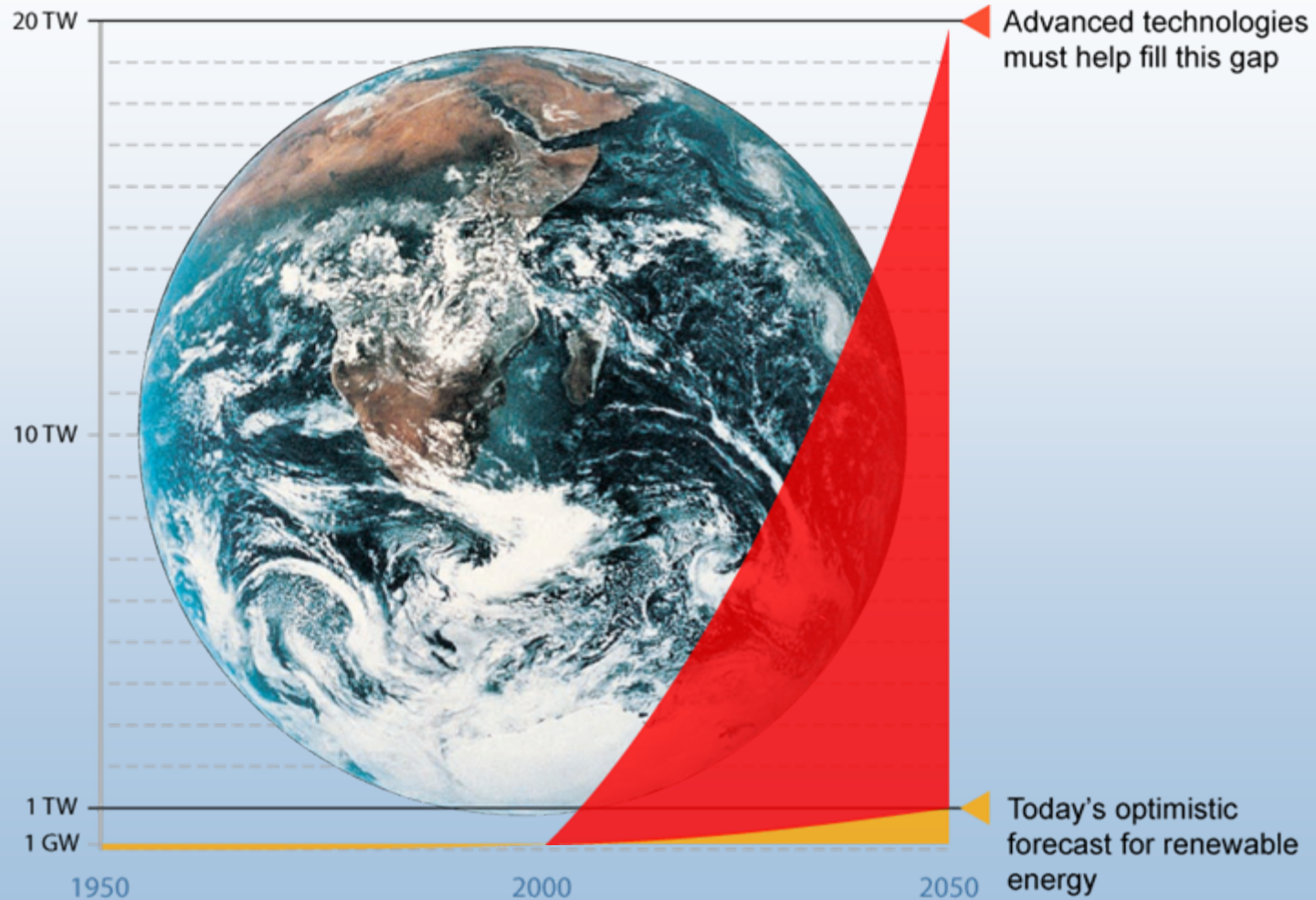


Energy Solutions Are Enormously Challenging

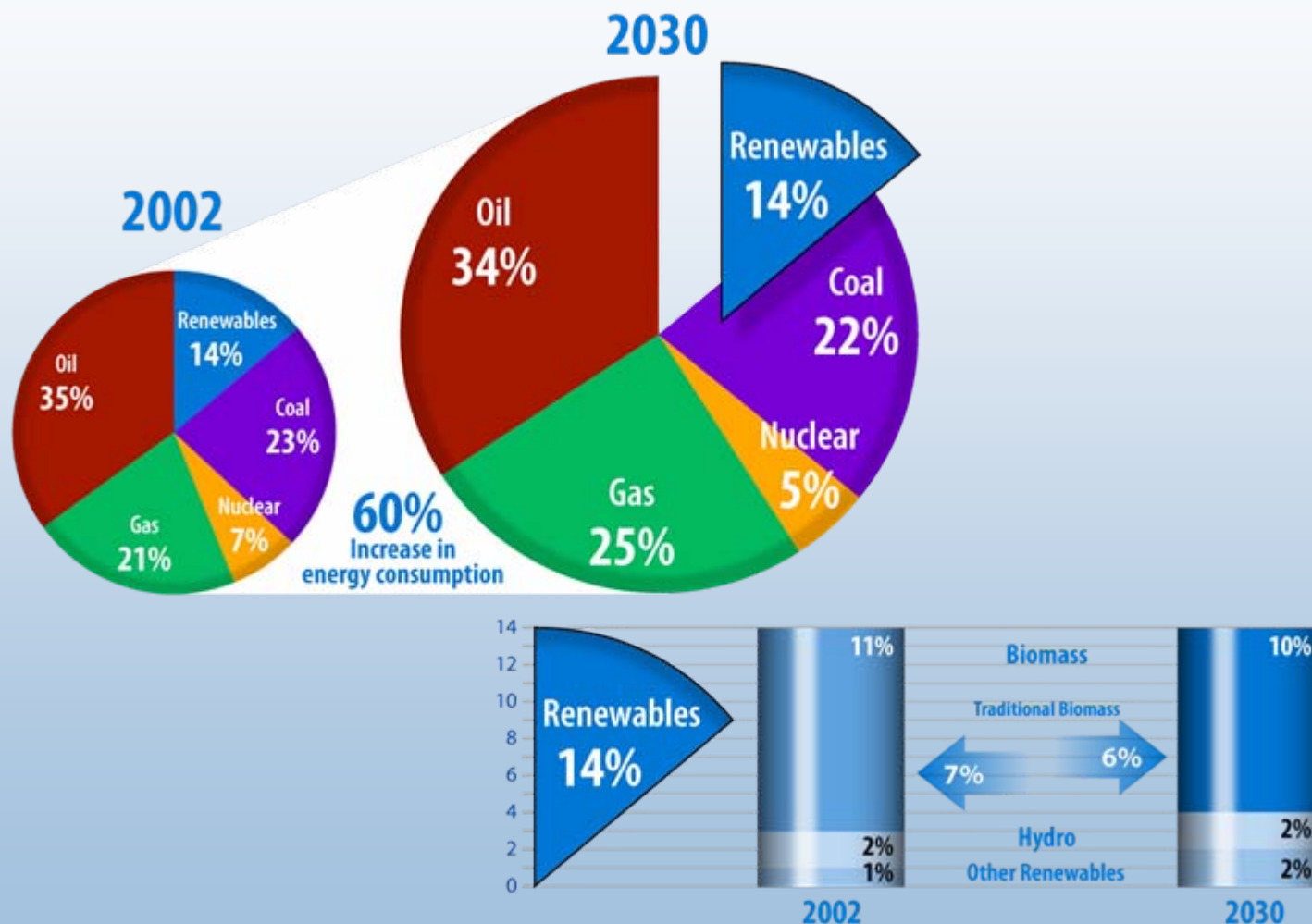


We need a balanced portfolio of options

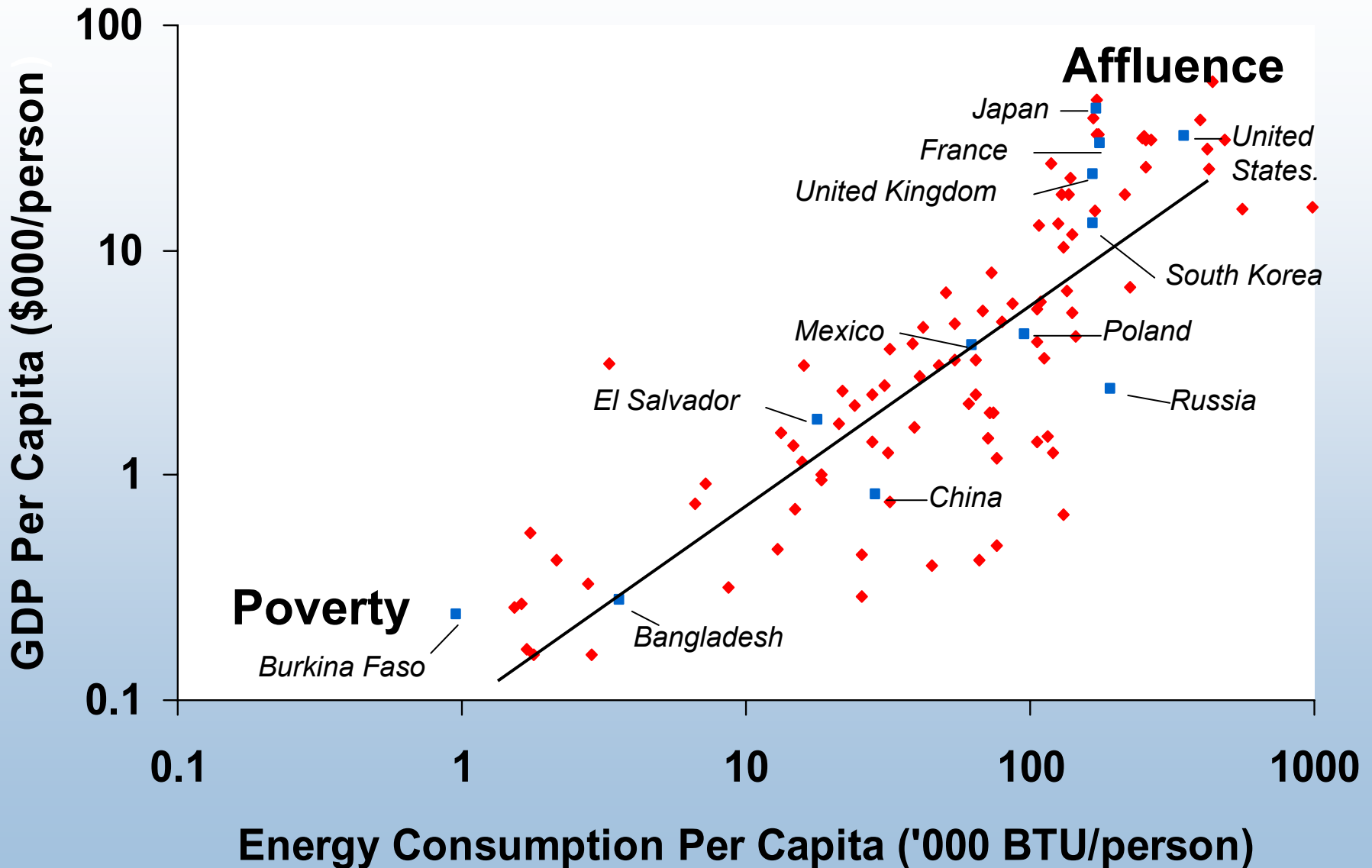
Magnitude of Challenge Requires Global Action and a Change in Trajectory



World Energy Supply and the Role of Renewable Energy

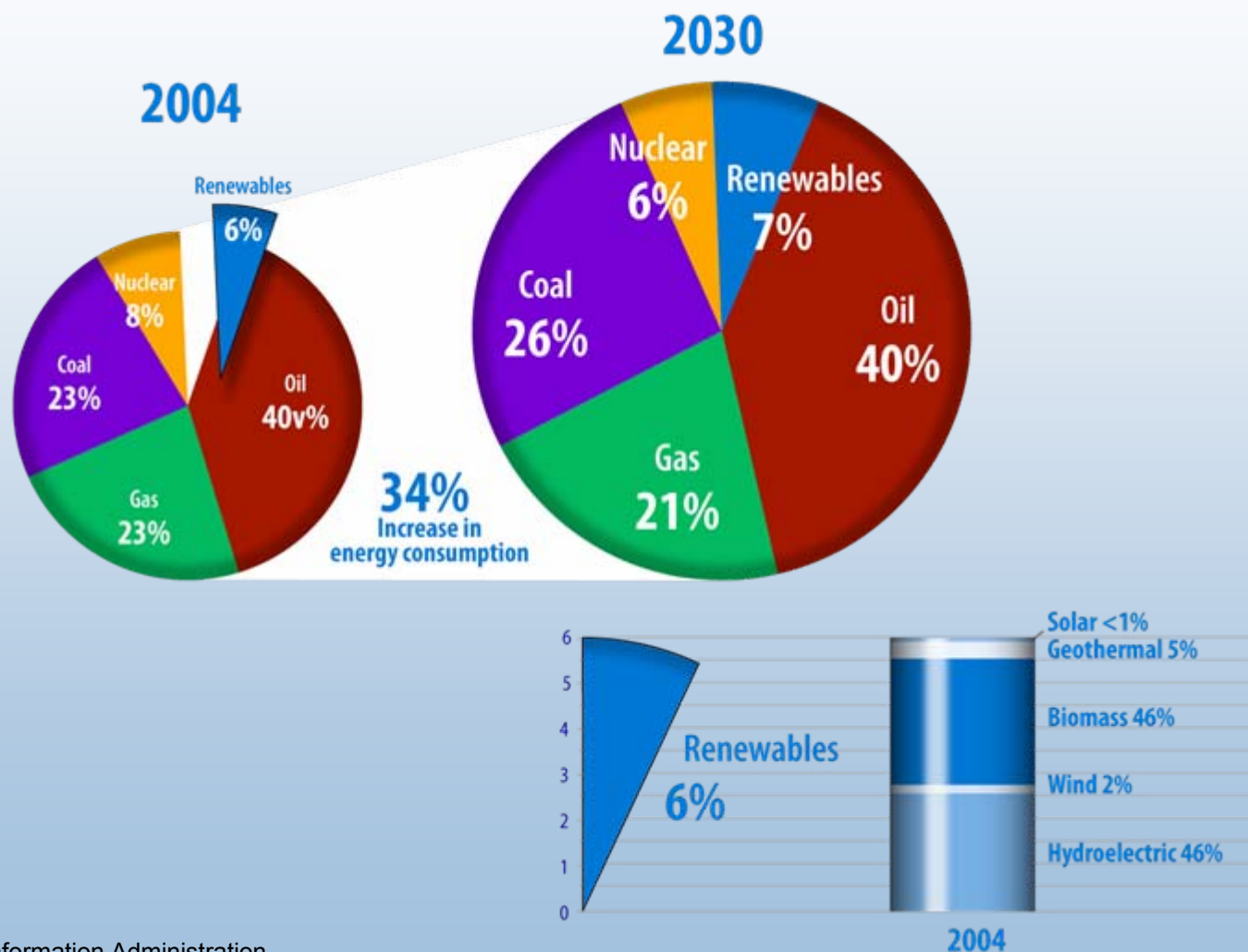


Energy Use and Gross Domestic Product



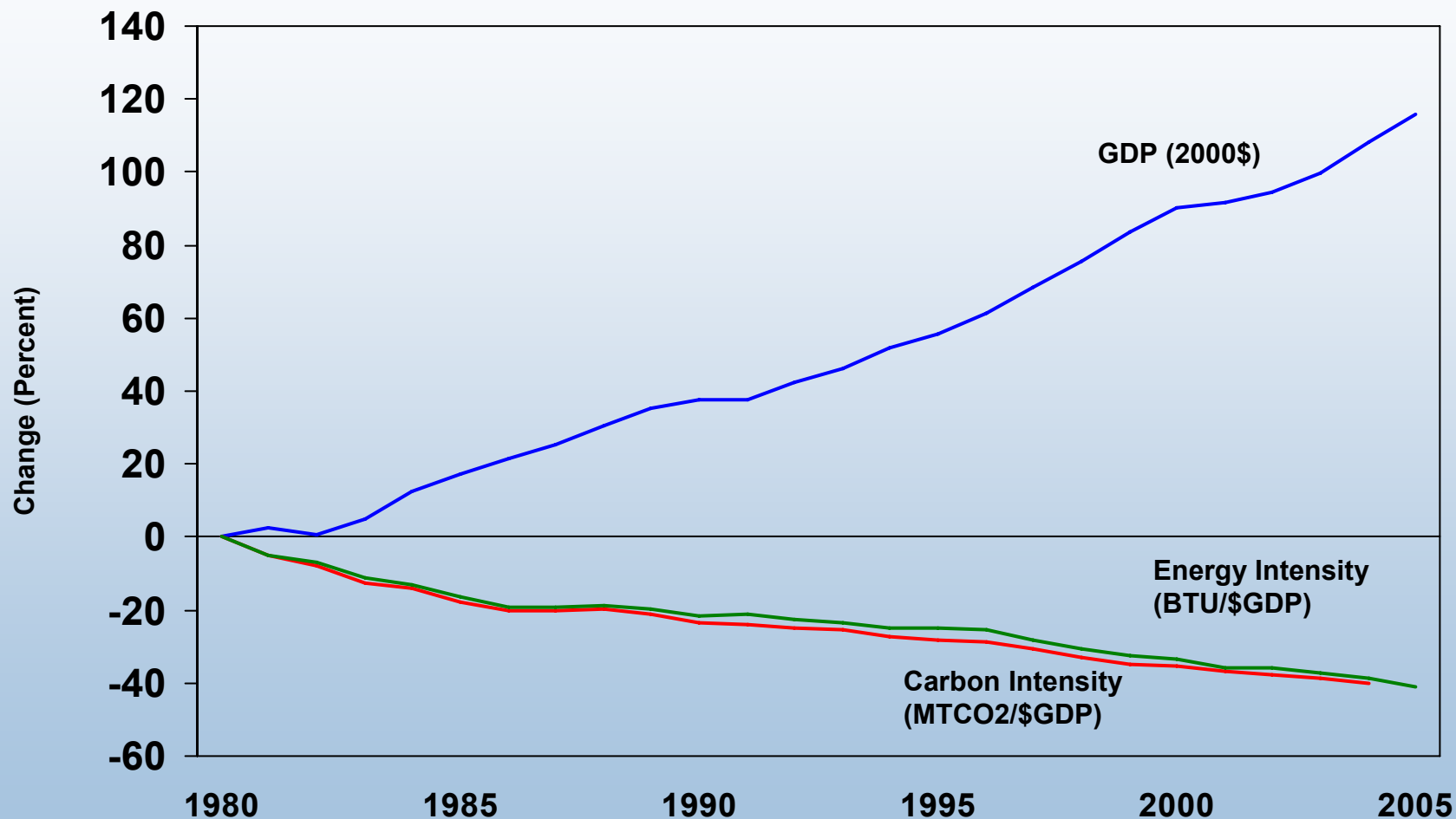
Source: Energy Information Administration, International Energy Annual 2000 Tables E1, B1, B2; Gross Domestic Product per capita is for 2000 in 1995 dollars. Updated May 2002

U.S. Energy Consumption and the Role of Renewable Energy



Source: Energy Information Administration,
Annual Energy Outlook 2006, Table D4

Carbon and Energy Intensity



Technology-Based Solutions:

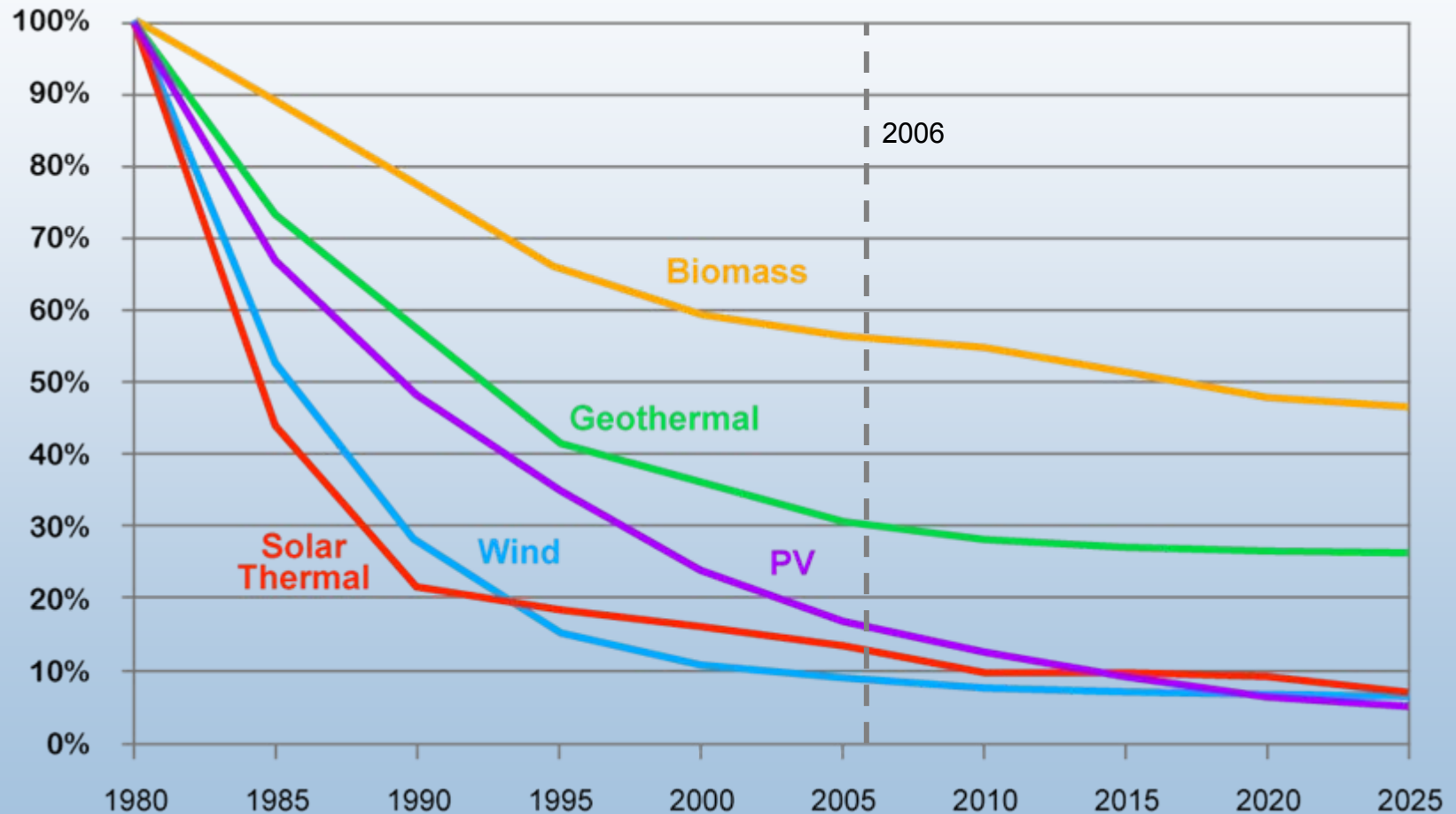
There is no single or simple answer

- Energy efficiency
- Renewable energy
- Nonpolluting transportation fuels
- Separation and capture of CO₂ from fossil fuels
- Next generation of nuclear fission and fusion technology
- Transition to smart, resilient, distributed energy systems coupled with pollution-free energy carriers such as hydrogen and electricity



Renewable Energy Costs Have Decreased

Historical and Projected

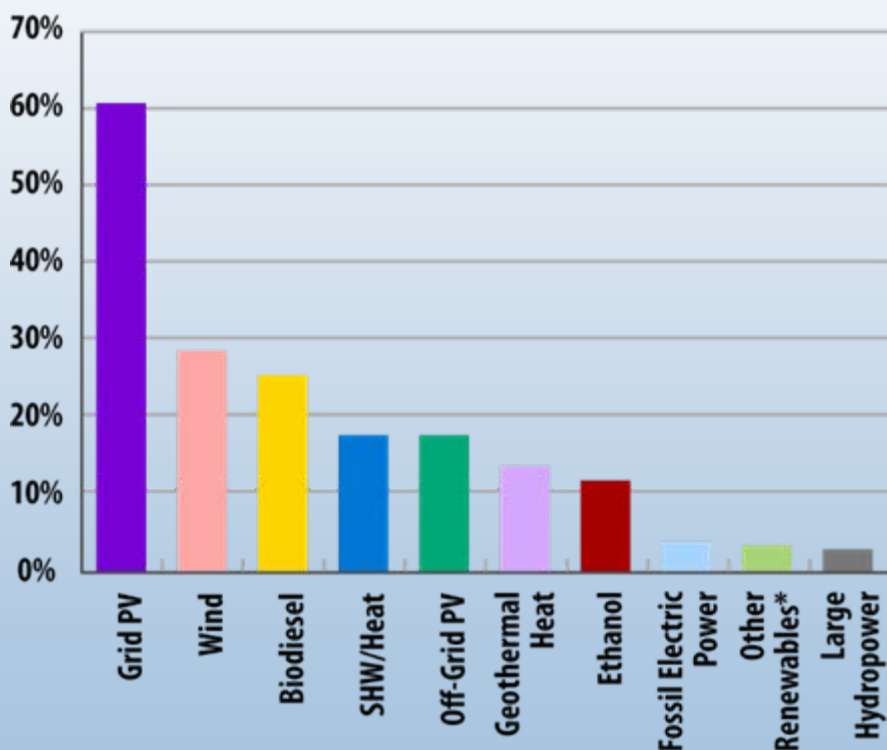


Costs as percentage of 1980 levels

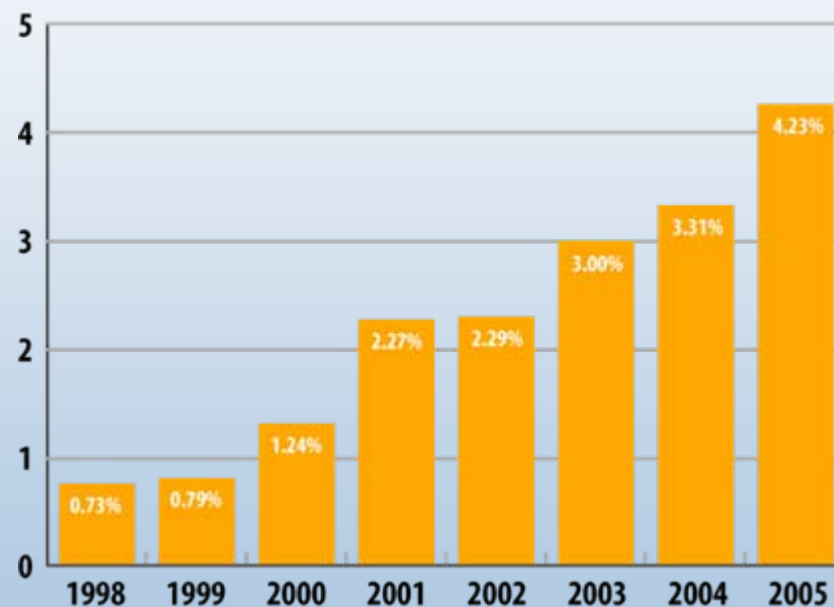
Source: NREL 2005, 2002

Renewable Energy Is Growing

Renewable Energy Annual Growth Rates 2000-2004



Energy-Tech Investments Percent of Total U.S. Venture Capital



Sources:

Renewables 2005 Global Status Report, REN21

Clean Energy Trends 2006, Nth Power LLC

Energy Efficiency and Renewable Energy Technology Development Programs



Efficient Energy Use

- Vehicle Technologies
- Building Technologies
- Industrial Technologies



Renewable Resources

- Wind
- Solar
- Biomass
- Geothermal



Energy Delivery and Storage

- Electricity Transmission and Distribution
- Alternative Fuels
- Hydrogen Delivery and Storage

Solar Photovoltaics

Status:

- 450 MW
- Cost 18-23¢/kWh

Potential:

- 11-18¢/kWh by 2010
- 5-10 ¢/kWh by 2015

NREL Research Thrusts:

- Higher efficiency devices
- New nanomaterials applications
- Advanced manufacturing techniques



Wind

Today's Status

- 10,000 MW installed as of August 2006
- Cost 6-9¢/kWh at good wind sites

DOE Cost Goals

- 3.6¢/kWh, onshore at low wind sites by 2012
- 5¢/kWh, offshore in shallow water by 2014

Long Term Potential

- 20% of the nation's electricity supply

NREL Research Thrusts

- Low wind speed technology
- Distributed wind technology
- Advanced rotor development
- Utility grid integration



Biofuels

Biofuels status

- Biodiesel – 75 million gallons (2005)
- Corn ethanol
 - 81 commercial plants
 - 3.9 billion gallons (2005)
 - Today's cost ~\$1.35/gallon of gasoline equivalent (gge)
- Cellulosic ethanol
 - Projected commercial cost ~\$3.00/gge

Potential

- 2012 goal – cellulosic ethanol ~\$1.42/gge
- 2030 goal – all ethanol = 30% of transportation fuels

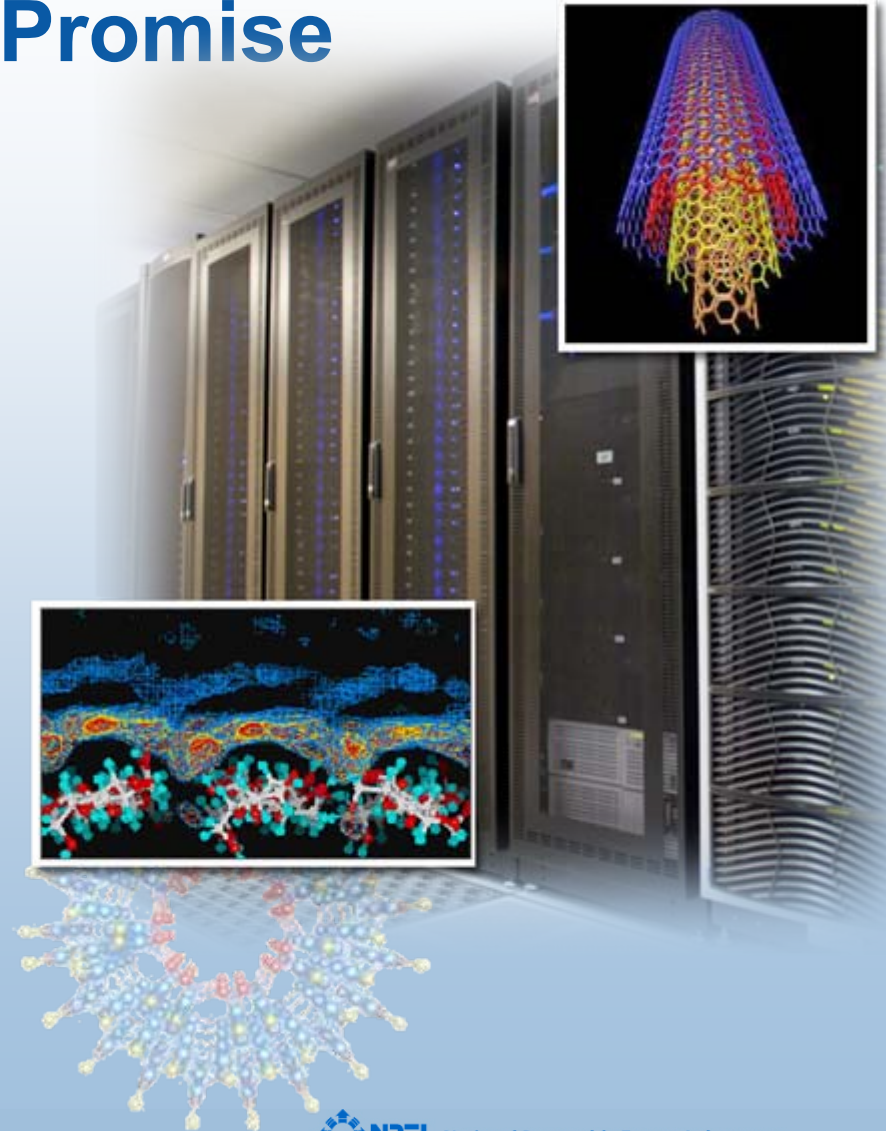
NREL Research Thrusts

- The Biorefinery
- Solutions to under-utilized waste residues
- Energy crops



Harnessing Innovation in Renewable Energy Science and Technology: The Future Promise

- Supercomputers
- Genomics
- Nanoscience
- Cellulosic and biofuels applications
- Hydrogen



Nano/Bio/Info

NREL as a Resource for Economic Development

- Total FY05 Colorado contribution - \$128 million
- Partnerships with Colorado universities
- Support for Colorado economic development community
- Education programs annually reach 25,000 teachers, students and consumers
- NREL and staff contributed \$135,000 to local charitable organizations
- Underwrote and designed first-ever Net Zero Energy Habitat House in Wheat Ridge

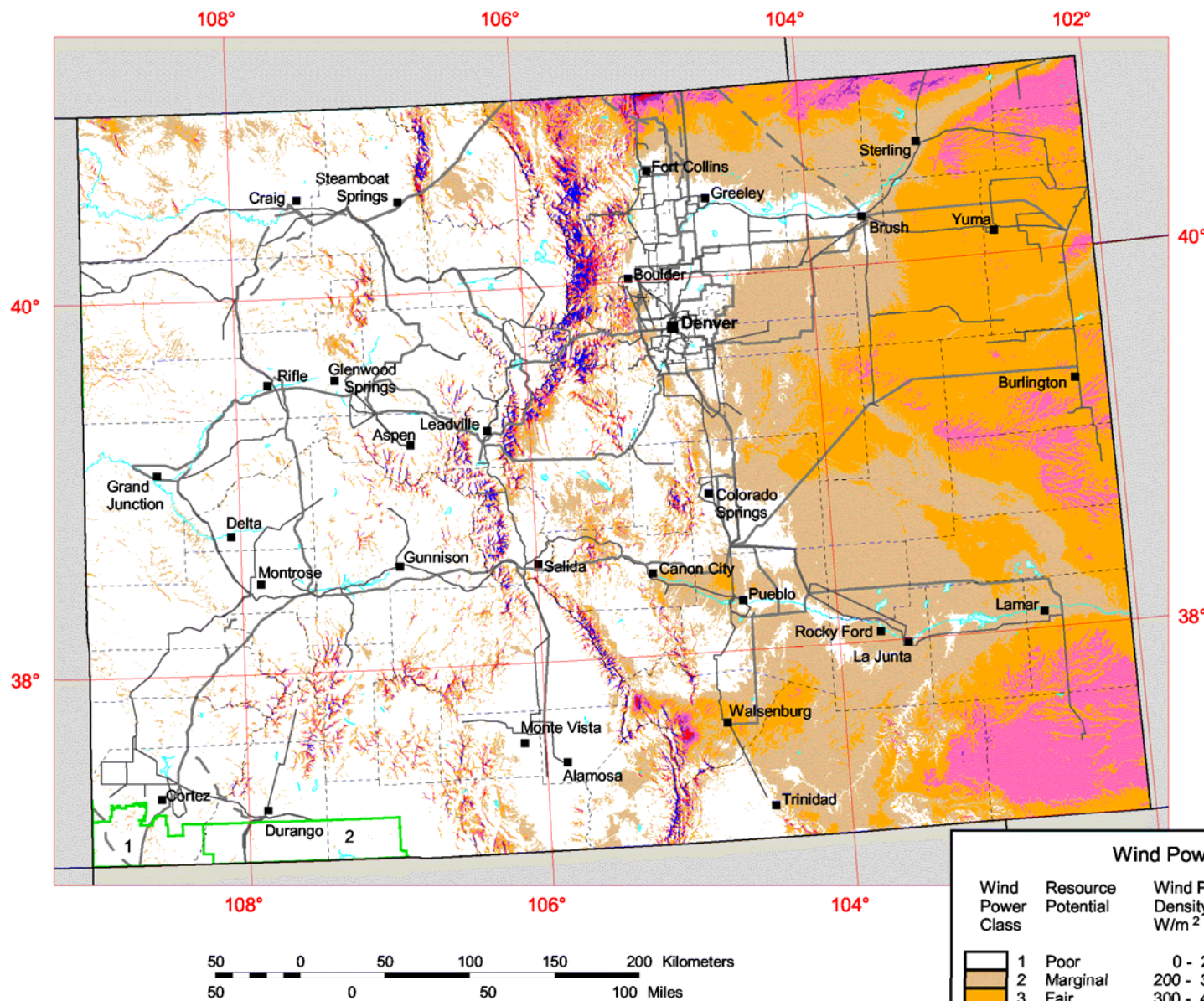
Renewable Energy: Enabling Economic Growth in Colorado

- Plentiful resources
- Centers of Excellence
- Business environment



Colorado

50 m Wind Power



Transmission Line* Voltage (kV)

- 115 - 161
- 230
- - - 345

* Source: POWERmap, ©2003
Platts, a Division of the
McGraw-Hill Companies

The annual wind power estimates for this map were produced by TrueWind Solutions using their Mesomap system and historical weather data. It has been validated with available surface data by NREL and wind energy meteorological consultants.

Wind Power Classification

Wind Power Class	Resource Potential	Wind Power Density at 50 m W/m ²	Wind Speed ^a at 50 m m/s	Wind Speed ^a at 50 m mph
1	Poor	0 - 200	0.0 - 5.9	0.0 - 13.2
2	Marginal	200 - 300	5.9 - 6.7	13.2 - 15.0
3	Fair	300 - 400	6.7 - 7.4	15.0 - 16.6
4	Good	400 - 500	7.4 - 7.9	16.6 - 17.7
5	Excellent	500 - 600	7.9 - 8.4	17.7 - 18.8
6	Outstanding	600 - 800	8.4 - 9.3	18.8 - 20.8
7	Superb	> 800	> 9.3	> 20.8

^a Wind speeds are based on a Weibull k of 2.0 at 1500 m elevation.



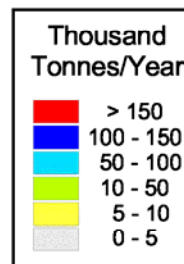
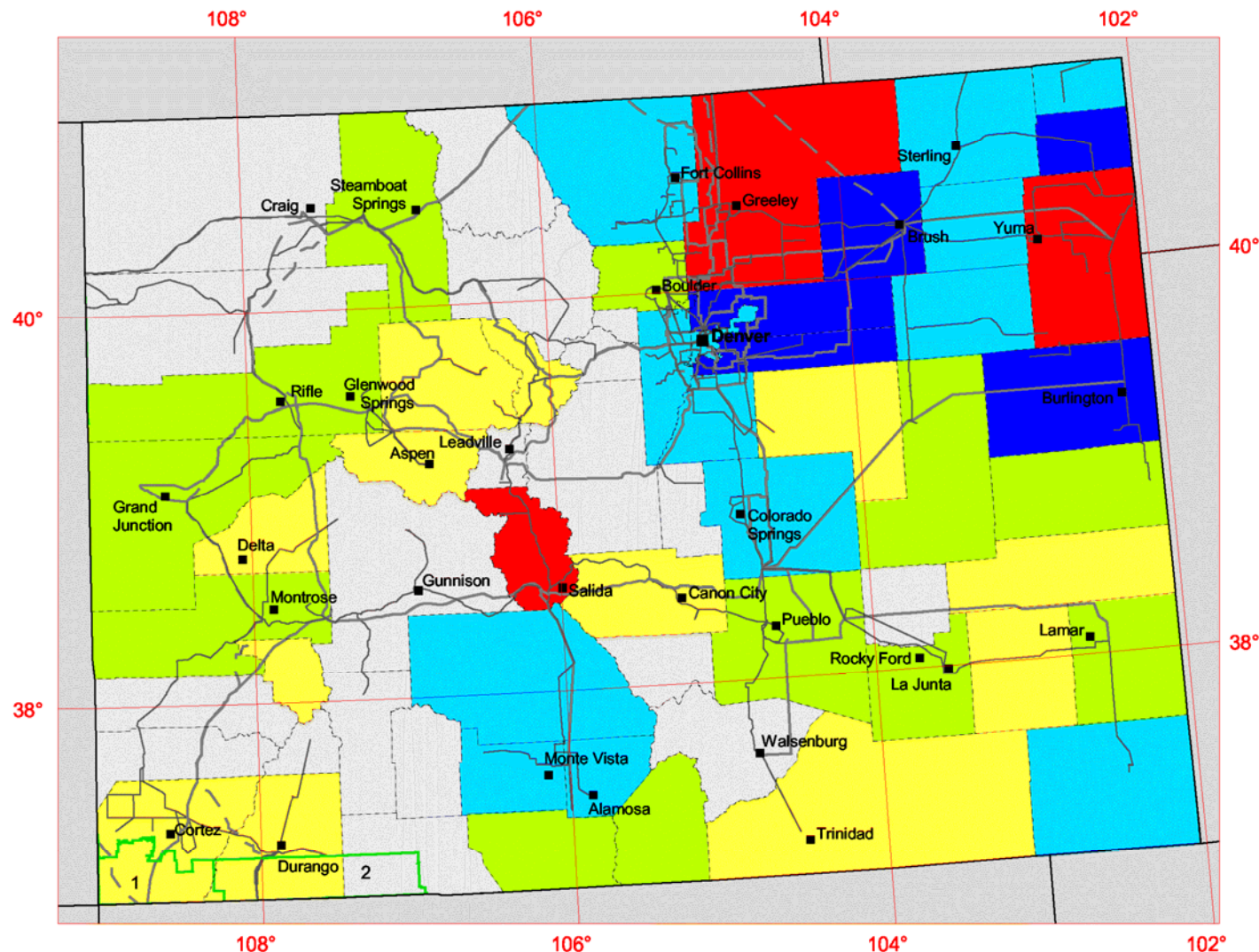
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Indian Reservation

- 1 Ute Mountain
- 2 Southern Ute

Colorado

Biomass Resource



This study estimates the technical biomass resources available in the United States by county, based on one year of production. It includes the following feedstock categories:

- Agricultural residues (crops and animal manure);
- Wood residues (forest, primary mill, secondary mill, and urban wood);
- Municipal discards (methane emissions from landfills and wastewater treatment plants);
- Dedicated energy crops (on Conservation Reserve Program and Abandoned Mine Lands).

This data is still under review by NREL.

Transmission Line*

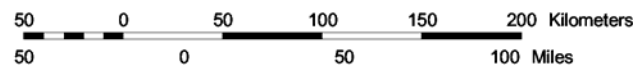
Voltage (kV)

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* Source: POWERmap, ©2003
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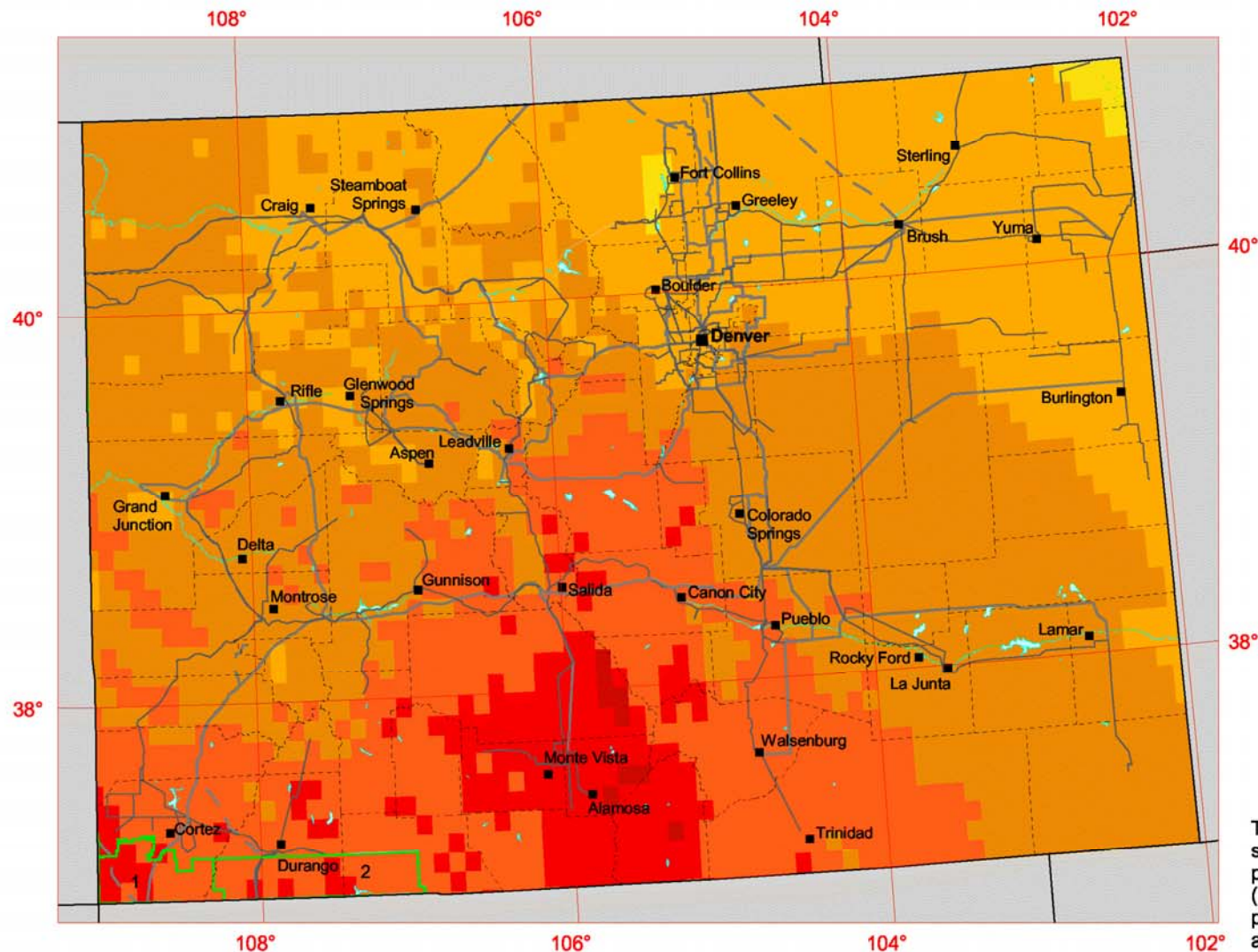
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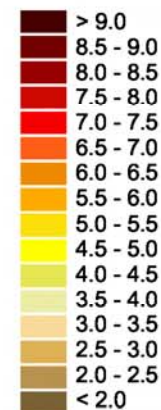




Colorado

Direct Normal Solar Resource

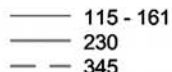
Solar Resource kWh/m²/day



The annual solar resource estimates shown are for a 1-axis tracking flat plate collector. It is a 5-year average (1998-2002) with 10 km resolution, produced by Richard Perez (SUNY) and adjusted by NREL.

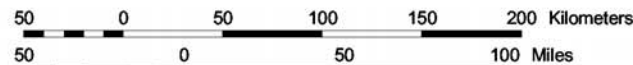
Transmission Line*

Voltage (kV)



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Indian Reservation



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National Renewable Energy Laboratory



Renewable Energy: Getting There Involves...

Technologies

- Efficient buildings and vehicles
- New biofuels
- Clean generation
- Storage

**Reducing
Risk**



**Mobilizing
Capital**

Policies

- Predictable
and consistent

Markets

- Infrastructure
- First plant costs
- Supplier/consumer
acceptance

The U.S. Department of Energy's National Renewable Energy Laboratory

www.nrel.gov



Golden, Colorado